DOCUMENT RESUME

ED 244 806 SE 044 531

AUTHOR Cohen, Herbert G.
TITLE A Comparison of the Development of Spatial Conceptual Abilities of Students from Two Cultures.
PUB DATE 84
NOTE 22p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (57th, New Orleans, LA, April 27-30, 1984).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Cultural Differences; *Elementary School Science; Intermediate Grades; *Perceptual Development; *Reservation American Indians; Science Education; Secondary Education; *Secondary School Science; *Spatial Ability
IDENTIFIERS Piagetian Tasks; Science Education Research

ABSTRACT

Efforts are underway to determine if there are any unique ways to Navajo thinking and thus to the way they might learn. Studies have shown a consistent lag in achievement levels for Native Americans, especially after seventh grade. At least three possible explanations for this phenomenon are viable: (1) They are deficient in the needed skills to learn school subjects. (2) They have a different pattern for learning and processing information compared to individuals in the dominant culture. (3) They possess a world view vastly different from Americans at large. Therefore, this investigation examined whether there are time delays or time advances in the development of selected spatial abilities of a Navajo student sample compared to an equivalent non-American Indian student sample. A battery of 10 Piagetian-type tasks (designed to examine projective and Euclidean spatial thinking abilities) was administered to students in grade 6 (N=22), grade 8 (N=20), and grade 10 (N=24). Results indicate that Navajo students' spatial ability develops at approximately the same rate as does spatial conceptual ability of non-American Indian students. Therefore, further investigation must be pursued to determine which factor or factors underlie the lag in achievement levels. (Author/JN)

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A Comparison of the Development of Spatial Conceptual Abilities of Students from Two Cultures

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Herbert G. Cohen

Arizona State University

57th Annual Meeting National Association for Research in Science Teaching

New Orleans, April 27-30, 1984

SE044531

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INTRODUCTION

Does Piaget's system really offer a universal point of view? Many cross-cultural studies examining Piaget's system have been conducted worldwide in such locales as Senegal, Iran, Algeria, Canada, the United States and elsewhere (Bruner, 1966). On the whole, these studies have substantiated the theoretical construct of Piaget's stages, and their invariant succession in development, although at times the acquisition of a stage may be delayed. A child may develop a certain structure, inferred from the presence of a particular ability, earlier or later than another child, but in normal development both individuals will pass through an identical sequence of stages regardless of their geographic locale or their social-cultural milieu. Dasen and Heron (1980) support the preceding position in their review of cross-cultural studies:

> "The most important finding of almost all studies may be overlooked, namely that the same sequence of substages has been found everywhere, and for every concept in the concrete operational stage studied thus far. Here again we have a commonality which supports strongly the universalist position of Piaget's theory" (p. 308).

Dasen and Heron further state that there are both qualitative and quantitative differences between groups within the concrete operational stage as elaborated by Piagetian theory. However, they emphasize that "two concepts that develop congruently in the average Genevan child may develop

at very different rates in another culture, if one of them is more highly valued (that is, more relevant and adaptive in that other culture" (p. 327). Piaget (1970) took the position that factors such as cultural differences, language and education might be expected to accelerate or delay the average chronological ages at which the stages are attained, or the detail of "the conceptualizations but not the operations themselves." Berry (1976) supported this notion suggesting that survival skills in a particular ecology and its associated economy favor the earlier development of specific spatial cognitive abilities over other spatial abilities. Dasen's findings (1975) that spatial conceptual abilities developing during the concrete operational stage occurred earlier in a sample of Eskimo children, who belonged to a nomadic group, than in a sample of West African agriculturists, who were relatively sedentary, with a sample of Australian Aborigines showing an intermediary rate of development lend further support the notion that the environment effects cognitive development.

Anthropologists have come increasingly to the study of folk or native cognition (Spradley, 1972; Tyler, 1969). One product of such research in this tradition is an ethnographic study of Navajo spatial relations (Pinxten, 1980). Pinxten again raised the question of the effects of cultural difference, that is, does the cultural milieu in which one develops have a significant effect on one's cognitive development? Pinxten also voiced the concern about the formal teaching of science and mathematics in Non-Western Cultures. He suggests that most teaching practices are geared towards Western thinking patterns, and that these practices might not be appropriate to societies in which spatial cognition may possibly develop in ways dissimilar to

Western patterns of development.

Many areas of study include thinking about one's spatial environment. Certain subjects in the areas of science and mathematics are presented to students as if all students conceptualize their spatial surroundings in the same manner. For example, formal courses in geometry, physical chemistry, and geology, to name but a few, have been historically presented to students using a supposed Western model of how people are supposed to think spatially. The presentation of curricula areas such as the aforementioned ones assumes that students, by the time they take such courses, have highly developed spatial abilities and that these abilities develop in a given order for all people. This assumption is open to question. If it is not true for all people it may very well affect their ability to master the subjects that are dependent on such understandings. Therefore, it follows that clarification of how people actually think about their spatial environment should be taken into consideration when teaching certain subjects.

Although many of the subjects taught at the Navajo Reservation Schools are taught in the same way as in traditional non-American Indian schools efforts are underway to determine if there are ways unique to Navajo thinking and thus to the way that they might learn. Studies have shown a consistent lag in achievement levels for American Indians, especially after the seventh grade (Fuchs and Havighurst, 1972). In the Southwest, American Indian ninth-graders are one to one and a half grade levels below the national average in mathematics achievement; by the twelfth grade the gap is 2.5 to 3 years (Bass, 1968). Add to this the fact that Native American students are one to three years older than the norm for their grade level (Berry, 1968)

and a sizable age differential becomes apparent. American Indian drop-out rates from high school are the highest in the nation, exceeding 50% in certain groups (Owens and Bass, 1969). Only 18% of American Indian high school graduates go on to college in the state of Arizona, and only 3% complete a 4-year course (Bass, 1969). The majority have low academic grade averages (McGrath, et.al., 1962). Less than 10% of Native Americans at Arizona's universities graduate in scientific or technical fields, whereas for the general population this percent approaches 25%.

Over the years, people who have come into contact with the Navajo have noted distinctive features of their orientation to space and the visual world (e.g., Collier, 1967; Pfeiffer cited in John, 1972; Cattey, 1980). This orientation is exemplified by many of their day-to-day practices and religious beliefs, as well as by many components of their language. Five main characteristics exemplify the Navajo world (Pinxten, 1980):

(1) The structure of the world - the world is considered to be comprised of two dishlike structures, the earth and heaven. The earth is considered to be stretched out in all directions, with heaven hanging above the earth upside down. This bowlshaped construction is represented in the hooghan or house, as well as in the wedding basket. All of these structures are thought of as being closed on all sides with the exception of the east.

(2) The dynamic nature of the universe - reflects the notion that everything has within it some sort of power on structuring principle which keeps it standing throughout changes and against forces that affect it.

(3) Boundedness of the world - center-periphery organization. For Navajos space is bounded in each cardinal direction by a Sacred Mountain, and thus the world is bordered in a horizontal plane. The ciruclar construction of hooghans and the wedding basket reflects these same boundaries. All things are seen as being structured around a center, not only objects, but also certain practices are exemplified by behavioral rules (sleep around the center of hooghan in clockwise formation) and beliefs (ceremonies are conducted in the center of the hooghans).

(4) Closedness of the world: the notion of order - Navajos believe that all that is, is and that nothing substantial can be added to the world. Also, everything in the Navajo world fits into a preconceived and orderly set of relationships.

(5) The interrelationship of everything in the Navajo universe - nothing is on its own; everything is imbedded in a complex network and thus is linked to the whole.

These five main characteristics permeate the whole of the Navajo's social-cultural environment. In addition these characteristics are reflected throughout the Navajo's language. An example of language variability given here deals with the notion of in/out; center/periphery and even more specifically, with internal/external. Only the English translation will be listed, and this is done to exemplify the diversity and the complexity of the Navajo language: 'inside (a container)';

'in it, inside (a relatively closed container)'; 'in, into something (a container)'; extending into, sticking into'; 'through (an opening in it)'; through something, completely through it'; 'in here, in there'; 'inside something, completely inside of it'; 'outside, out'; 'up and out'; 'the way in or out, doorway'; and 'come inside'. This complex and extensive array of terms relating to a single central concept is the rule rather than the exception in the Navajo language. Thus, an individual growing up in the Navajo environment is exposed to a very rich language and one might well expect that this should have a direct effect on an individual's cognitive development, and in particular, to an individual's cognitive development with respect to their spatial conceptual development. One might be tempted to predict that a Navajo's spatial conceptual development would be different than that of a non-Navajo.

The part/whole distinction seems relatively unimportant in Navajo thought. If one must conceptualize the whole, there is little need for explicit development of the part/whole concept, yet it is clearly necessary in the Western conceptual framework and for such geometrical tasks as determining congruence, as well when dealing with ratio and proportion.

In an activity such as contruction of an angle, one must be concerned with concepts of position, straight line, and distance. With any angle having a measure of 120 degrees, or more, Navajos typically no longer consider the figures to be angles, but merely lines or curves (Pinxten, 1980). The idea of angle is more easily understood if it is a corner of a closed design. Angles as corners are considered to be volumes and surfaces in the Navajo system. The notion of angle is essentially lacking

(Pinxten, 1980). The expression of straight line may be interpreted as any line made by man, no matter how crooked it is. It is also interpreted by direction of movement.

There is a Navajo word, ahaah, meaning, "together, in parallel." It means two objects next to each other, an object facing a person, two things sitting together, etc. It is also used to denote parallelism. Care must be exercised in distinguishing the meaning of parallel in the geometric sense and in the Navajo sense. In the Navajo sense, parallelism is a visual or dynamic reltaionship.

There is a Navajo concept of overlapping which is used to apply to every possible instance of one object, figure, or space covering or stretching out over or sitting upon, or in some way screening a second one. There need not be any further implication of contiguity. If the term superimposition is used to convey the notion of congruence, the Navajo may reasonably see a wide variety of different figures all being congruent. In addition, there is the pervasive notion in the Navajo culture that all things are part of a contiguous whole. If we consider the separate distinct parts of a geometric figure, such as may be done in determining the congruence of two figures, there is the real possibility the Navajo may in his or her own mind find difficulty thinking of the figures as separate entities. It may be hypothesized that congruence tasks may be difficult since only spaces which are bordered by clear limits are considered relevant. The notion of measurement by a fixed unit is alien.

The characteristics which constitute a physical system's volume versus the system's planar surface, are of major importance in Navajo spatial

structuring. This concept should assist Navajos with the concept of volume. However, by the same token, this concept may hamper Navajos in their understanding of surface area of solid figures.

Pinxten (1980) argues that the Western curriculum is able to take certain basic topological spatial notions for granted which are also found in the settlement pattern and man-made environment in most Western cultures. These are then built upon and elaborated in the systems of mathematics and reasoning. The Navajo system and pattern of spatial thought is built upon different basic principles. It is more akin to complex models of dynamic topology which have only begun to emerge in Western thought. The Navajo system of space and spatial relations has as its basic notions movement, volumes, planes and dimensions.

Piaget offers a model which can guide educators interested in promoting an understanding of concepts related to Euclidean geometry. From the psychological point of view, Piaget's research suggests that the concepts of straight line and elementary projective relations, together with the Euclidean concepts of distance and measurement, are derived from topological spatial conceptualizations (Piaget and Inhelder, 1967; Piaget, Inhelder and Szeminska, 1960). The theory is supported by other researchers (Dodwell, 1963; Forman, 1975; and, Laurendeau and Pinard, 1970).

Piaget and Inhelder state that topological conceptual abilities are generally developed by 7 or 8 years of age; those of projective space by 9 or 10 years, and Euclidean concepts by 11 or 12 years of age. A study by Dettrick (1974), conducted in the United States offers evidence that the development of both projective and Euclidean spatial concepts is

actually not completed until a later age, approximately 3 years beyond the ages suggested by Piaget, based on his study with a parallel Genevan group.

For Piaget the establishment of a system of references is one of the most important steps in the development of spatial concepts. When a system of reference is based solely on the elementary topological relations of order and proximity, it is then limited to particular configurations of objects without involving any reference point external to these objects. In order that an individual's spatial intuitions become operations representations, a projective system of perspectives must be formed which coordinates all possible viewpoints. Likewise, a stable Euclidean representational system must be elaborated, where distances and sizes are conserved, and the concepts of parallelism, similarities of figures, vertical and horizontal coordinates and the ability to reconstruct diagrammatical layouts develop.

Underlying the notion of the existence of differing conceptual abilities, is the construct of structures. According to Piaget structures are the organizational properties of intelligence, these structures being inferable from the behavioral contents whose nature they determine. They are the mental mechanism humans use to manipulate and act on data - that is relate, interpret, synthesize, clarify, order, predict, infer, and hypothesize.

Hallpike (1979) has undertaken a review of the anthropological literature on spatial relations using Piaget's theory as a guide. He concludes that non-western spatial relations are topological, and " . . . that the

development of conceptual representations of projective and Euclidean space is not a cognitive skill that emerges in all cultures ... but a highly specific skill closely related to schooling and literacy and to the cognitive demands imposed by the environment" (p. 335).

A great deal of the Navajo students' difficulty in science and mathematics may be attributable, therefore, to a prolonged, or even truncated developmental progression or just an alternative progression. The structures necessary for understanding and working with the axioms, postulates and problems in geometry may be incomplete or unavailable. Research on spatial cognition among groups with lifeways similar to the Navajo in the North Sahara (Bovet, 1974) and Sahel (Bovet and Othenin-Girard, 1975) regions of Africa give credence to such a suggestion.

The primary purpose of this investigation was to examine whether there is time delays or time advances in the development of selected spatial abilities of a Navajo student sample as compared to that of a comparable non-American Indian student sample.

METHOD

The data for this study were collected during late October, 1982, at the Rough Rock Demonstration School, Rough Rock, Arizona, and during January, 1983, at an elementary and a high school in Mesa, Arizona.

The Rough Rock Demonstration School is located in Northwestern Arizona, located on the Navajo Reservation, and is geographically isolated from the dominant non-Indian population surrounding the Reservation. This isolation leads to a minimum of contact with the non-Indian population and its cultural values. Furthermore, traditional ways of thinking are encouraged in the

students' homes, communities, as well as at the Rough Rock Demonstration School. The city of Mesa is located near Phoenix, Arizona, near the geographic center of the state. The student population at the Rough Rock Demonstration School was 100% Navajo, while the student population in the Mesa Public Schools was approximately: White - 85%; Black - 2%; Hispanic - 10%; American Indian - 2%; Pacific Islanders or Asian - 1%.

The Rough Rock Demonstration School has a population in excess of 500, and most of the children came from traditional families living within a 20 mile radius of the school. The school's curriculum in all academic areas was basically the same as that encountered in the majority of non-American Indian schools. Mesa's school system is composed of 32 elementary schools, 5 junior high schools, 5 senior high schools and 3 special schools. The total population in the Mesa schools is approximately 40,000.

Sample Both sixth and tenth grade students were tested at both sites. At the Rough Rock (Navajo) site 22 sixth graders and 24 tenth graders were in the subsamples. In the Mesa sample 34 sixth graders were examined as well as 34 subjects in the tenth grade. The entire sixth grade at both the Mesa and Rough Rock Elementary Schools were involved in similar curricular programs with respect to mathematics and science. Subjects were randomly selected to participate in this study from these sixth grade pools. The pool of tenth grade subjects from both sites consisted of only those subjects participating in a mathematics course as well as a science course. Again the samples were randomly selected from these tenth grade

pools. The respective courses at both sites were equivalent in nature. Also similar materials were used at both sites for instructional purposes.

All of the sixth graders at both sites were receiving instruction in sixth grade arithmetic. The tenth graders at both sites were all taking a mathematics and a science course.

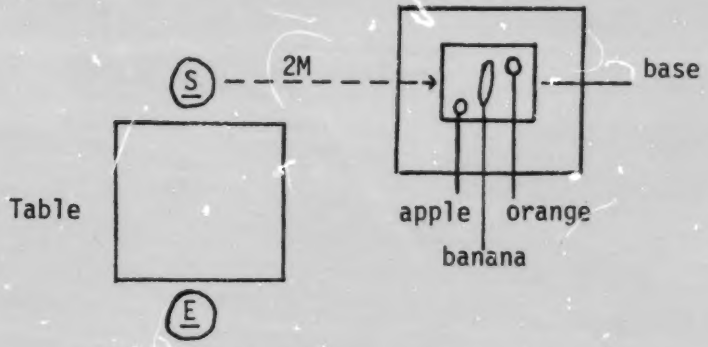
The average age of the sixth grade students at the Rough Rock site was 12 years 6 months at the time of the data collection, while that of the sixth graders at the Mesa site was 11 years, 7 months. The respective ages for the tenth grade students was 16 years, 9 months and 15 years, 9 months.

Measure A battery of ten Piagetian-type tasks designed to examine the students' projective and Euclidean spatial thinking abilities was individually administered in a randomized order. These tasks were designed on the basis of information provided by Piaget and Inhelder (1967) and described elsewhere (Phillips, 1981). Each task permits the subject being interviewed to interact with objects (either overtly or representationally) and to respond to questions regarding his or her actions upon the objects. The protocols require that the subject supply an acceptable reason for a choice. If a subject was able to complete each part without error he/she was given a "pass." Otherwise, the subject was given a "fail."

The following tasks were used: P_1 (Addition and subtraction of projective elements); P_2 (Complementary perspective relations); P_3 (One-to-many multiplication of projective elements); P_4 (One-to-one multiplication of projective elements); P_5 (Rectilinear order); P_7 (One-to-many multiplication of projective relations); P_8 (One-to-one multiplication of pro-

jective relations); E_5 (Placement and displacement of objects); E_6 (Inclusion of intervals or distances); and, E_8 (One-to-one multiplication of placement and displacement relations). Each task was scored on the basis of predetermined criteria. These criteria were derived from the literature (Ott, 1977; Doyle, 1977; Treagust, 1978; and, Morgan, 1979). A sample task is provided in Figure 1.* Analyses of task performance performed by Ott, Doyle, Treagust and Morgan using a Chilton modified Gutmann Scalogram analysis (Edwards, 1957) procedure provided evidence that these tasks do form a unidimensional scale, and therefore have the requisite sensitivity to detect performance differences over the age range of the subject in this study.

Figure 1: Protocol for IGP_1: Addition and subtraction of projective elements.



The subject(s) is given a piece of white paper and three crayons (orange, yellow and red).

The experimenter says to the subject: "Make a drawing which shows exactly the way these pieces of fruit look to you."

*Copies of the tasks used in this study may be obtained by writing to the author.

Scoring Criteria

"Pass" - Makes acceptable drawing showing masking of the right portion of the banana and the lower portion of the orange, and provides an acceptable explanation for the drawing including the notion that all parts of these pieces of fruit could not be seen due to masking.

"Fail" - Does not make an acceptable drawing and/or does not provide an acceptable explanation.

RESULTS

To test for significant differences between the two groups, that is the students from Mesa and the students from Rough Rock on each task, a chi-square one sample procedure (Siegal, 1956, pp. 42-47) was used. The results of these analyses for the sixth graders are show in Table I and for the tenth graders, in Table II. Significant differences in performance between groups were detected for P_1 (X^2 = 6.73, P = .05, df=1) and P_8 (X^2 = 13.50, P = .05, df=1) at the sixth grade level, and E_8 (X^2 = 5.63, P = .05, df=1) at the tenth grade level.

DISCUSSION

The overall findings of this study support the contention that there were no substantial time delays or advances in the development of selected spatial abilities of Navajo sixth and tenth grade students compared to those of parallel non-American Indian students. (One should keep in mind that for both grade levels, the Navajo subjects were approximately one year older than the parallel non-American Indian subjects.) This supports the contention concerning the invariant nature of spatial cognitive development regard-

less of the cultural milieu in which it occurs. In addition, these findings suggest that although other variables, such as rate of physical maturation, may possibly have an effect on spatial cognitive development, the effect is minimal, and for practical purposes may be disregarded. These findings seem to negate both Hallpike's (1979) and Pinxten's (1980) concerns with respect to the influence of one's cultural milieu on the development of cognition in general, and spatial conceptualizations in particular. Both argue that non-Western spatial relations are topological in nature. Pinxten (1980) suggests that the Navajo system and pattern of spatial thought is built upon different basic principles, being more akin to complex models of dynamic topology. The Navajo system has as its basic notions of movement, notions concerning volumes and the planes of an object or an environment, and dimensions. Hallpike argues that projective and Euclidean spatial conceptualizations are not cognitive skills which emerge in all cultures, but rather a highly specific skill related to schooling and literacy and to the cognitive demands imposed by the environment, and thus may vary from culture to culture.

Indeed the findings of this study suggest that Navajo systems of spatial reasoning and pattern do not appear to differ markedly to that of the other group tested, and that both group's systems of spatial reasoning and pattern are similar to other groups reported in the past. (Phillips, 1982; Morgan, 1979; Treagust, 1978; Cohen, 1978; Doyle, 1977; Ott, 1977; Forman, 1975; Dettrick, 1974; Abravanel, 1973; Laurendeau and Pinard, 1970; Piaget and Inhelder, 1967; Bruner, 1966; and, Dodwell, 1963.)

Navajo students' spatial conceptual ability develops at approximately the same rate as does spatial conceptual ability of non-American Indian students. By the time Navajo students reach high school

age and proceed to study mathematics and science courses which require moderately sophisticated spatial thinking abilities, they appear to have the requisite cognitive structures to do so. The concern of modifying instruction in these courses in order to adapt them to the supposed 'different' structures possessed by Navajo adolescents is unfounded. Navajo children living on the reservation exist in an environment in which overtly their culture has a view of the spatial environment differing from that of non-American Indians. This is exemplified by their culture's language which has unique meanings for spatial relationships. The results of this study indicate that Navajo school children's development of spatial ability is more-or-less the same as that which occurs among other people studied. Therefore, one must look elsewhere, that is, other than for a difference in spatial conceptual development, to determine the causative agents for the consistent lag in achievement levels for Navajos. This factor is extremely important and should be vigorously examined. Examination of other factors may prove to be fruitful. Possibly with information such as this in hand instructional strategies might be implemented to help to overcome the deficit presently exhibited by these Navajo students.

TABLE I

Analysis of Performance Between Sixth Graders From Mesa and Rough Rock on Spatial Tasks

		Number of Passing Scores on Each Task									
Location	N	P_1	P_2	P_3	P_4	P_5	P_7	P_8	E_5	E_6	E_8
Rough Rock	22	10	6	10	10	6	10	16	16	0	16
Mesa	34	28	15	25	20	11	20	9	30	7	22
TOTAL	56	38	21	35	30	17	30	25	46	7	38
X^2		6.73*	3.37	3.37	0.50	0.01	0.50	13.50*	1.26	3.47	0.85

* Significant at the 0.05 level, df=1

TABLE II

Analysis of Performance Between Tenth Graders From Mesa and Rough Rock on Spatial Tests

		Number of Passing Scores on Each Task									
Location	N	P_1	P_2	P_3	P_4	P_5	P_7	P_8	E_5	E_6	E_8
Rough Rock	24	24	18	22	16	12	18	14	20	2	16
Mesa	34	32	23	31	27	25	26	16	32	11	32
TOTAL	58	56	41	53	43	37	44	30	52	13	48
X^2		3.76	0.81	0.29	0.62	2.43	0.03	1.24	0.79	3.39	5.63*

*Significant at the 0.05 level, df=1

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